

WHAT IS CLAIMED IS:

- 1 1. A wireless communication receiver comprising:
2 an antenna array which comprises plural antennas, the plural antennas providing
3 respective plural signals indicative of an arriving wavefront;
4 a joint searcher and channel estimator which essentially concurrently considers
5 the plural signals provided by the plural antennas for determining both a time of arrival
6 and channel coefficient.

- 1 2. The apparatus of claim 1, wherein the joint searcher and channel estimator
2 essentially concurrently considers the plural signals provided by the plural antennas for
3 determining plural times of arrival and plural channel coefficients, an arriving
4 wavefront being represented by one of the plural times of arrival and a corresponding
5 one of the plural channel coefficients.

- 1 3. The apparatus of claim 1, wherein the time of arrival and the channel
2 coefficient are essentially concurrently determined by the joint searcher and channel
3 estimator.

- 1 4. The apparatus of claim 3, wherein the time channel coefficient is a composite
2 channel coefficient which takes into consideration channel impulse responses for
3 channels associated with each of the plural antennas in the antenna array.

- 1 5. The apparatus of claim 1, further comprising a detector which utilizes the
2 channel coefficient and the time of arrival to provide a symbol estimate.

- 1 6. The apparatus of claim 1, wherein the wireless communication receiver is a
2 mobile terminal.

- 1 7. The apparatus of claim 1, wherein the wireless communication receiver is a
2 network node.

- 1 8. The apparatus of claim 1, wherein the antenna array comprises a uniform
2 linear array of plural antennas.

1 9. The apparatus of claim 1, wherein each of the plural antennas in the antenna
2 array is represented by an antenna index, and wherein the joint searcher and channel
3 estimator comprises:

4 an antenna signal matrix in which a complex value indicative of the signal
5 received in a sampling window is stored as a function of a sampling window time index
6 and the antenna index;

7 a matrix analyzer matched in a spatial domain to a direction of arrival, the matrix
8 analyzer generating matrix analyzer output;

9 an output analyzer which uses the matrix analyzer output to generate the time of
10 arrival and the channel coefficient.

1 10. The apparatus of claim 1, wherein each of the plural antennas in the antenna
2 array is represented by an antenna index, and wherein the joint searcher and channel
3 estimator comprises:

4 an antenna signal matrix in which a complex value indicative of the signal
5 received in a sampling window is stored as a function of a sampling window time index
6 and the antenna index;

7 a correlator which performs a Fast Fourier Transformation (FFT) calculation to
8 generate a correlator output;

9 an correlator output analyzer which uses the correlator output to generate the
10 time of arrival and the channel coefficient.

1 11. The apparatus of claim 10, wherein in performing the calculation the
2 correlator considers a dimensional receptivity vector formed from the antenna signal
3 matrix with respect to a sampling window time index for the plural antennas of the
4 antenna array, the dimensional receptivity vector having a frequency related to a
5 difference between phase components of complex values of the dimensional receptivity
6 vector, there being plural possible frequencies for the dimensional receptivity, the
7 plural possible frequencies being represented by a frequency index; and

8 wherein for each combination of plural possible frequencies and plural time
9 indexes, the correlator calculates:

10
$$Y(n,t) = FFT(n, X(:,t))$$

11 wherein t is the sampling window time index;

12 $X(:,t)$ is the complex antenna matrix, with : representing all antenna indexes for
 13 one sampling window time index;
 14 n is the frequency index.

1 12. The apparatus of claim 11, wherein for each combination of plural possible
 2 frequencies and plural time indexes, the correlator calculates:

$$Y(n,t) = \sum C_j * FFT(n, X(:,t)), j = 1, K$$

4 wherein C_j is a coding sequence symbol value j and K is a length of the coding
 5 sequence.

1 13. The apparatus of 11, wherein each of the plural possible frequencies for the
 2 dimensional receptivity vector represents a different possible direction of arrival of the
 3 arriving wavefront.

1 14. The apparatus of 11, wherein the correlator output comprises $Y(n,t)$, and
 2 wherein the correlator output analyzer determines a maximum absolute value
 3 $|Y(n,t)|_{max}$, wherein the analyzer uses a sampling window time index t_{max} at which
 4 $|Y(n,t)|_{max}$ occurs as the time of arrival of the arriving wavefront; and wherein the
 5 analyzer uses the a frequency index n_{max} at which $|Y(n,t)|_{max}$ occurs as the direction
 6 of arrival of the arriving wavefront.

1 15. The apparatus of 14, wherein the correlator output comprises $Y(n,t)$, and
 2 wherein for each arriving wavefront the correlator output analyzer determines a
 3 qualifying absolute value $|Y(n,t)|_{max}$, wherein the analyzer uses a sampling window time
 4 index t_{max} at which $|Y(n,t)|_{max}$ occurs as the time of arrival of the arriving wavefront;
 5 and wherein the analyzer uses the a frequency index n_{max} at which $|Y(n,t)|_{max}$ occurs
 6 as the direction of arrival of the arriving wavefront.

1 16. The apparatus of 11, wherein the correlator output comprises $Y(n,t)$, and
 2 wherein the analyzer determines a maximum absolute value $|Y(n,t)|_{max}$, wherein the
 3 analyzer obtains an amplitude for the arriving wavefront by dividing $|Y(n,t)|_{max}$ by a
 4 number of antennas comprising the antenna array.

1 17. The apparatus of claim 1, wherein each of the plural antennas in the array is
2 represented by an antenna index, and wherein the joint searcher and channel estimator
3 comprises:

4 an antenna signal matrix in which a complex value indicative of the signal
5 received in a sampling window is stored as a function of a sampling window time index
6 and the antenna index;

7 a parametric estimator which uses complex values in the antenna matrix to
8 generate a parametric estimation output vector;

9 an analyzer which uses the parametric output estimation vector to generate the
10 time of arrival and the channel coefficient.

1 18. The apparatus of claim 17, wherein each parameter in each time index
2 corresponds to a possible direction of arrival.

1 19. The apparatus of claim 17, wherein the analyzer uses absolute values of
2 elements of the parametric output estimation vector to determine the time of arrival and
3 direction of arrival of the arriving wavefront.

1 20. The apparatus of claim 19, wherein the parametric output estimation vector
2 has a sampling window time index and wherein for an element of the parametric output
3 estimation vector having a sufficiently high absolute value the analyzer uses a sampling
4 window time index for an element of the parametric output estimation vector having a
5 sufficiently high absolute value to determine the time of arrival of the arriving
6 wavefront.

1 21. A method of operating a wireless communication receiver comprising:
2 obtaining from plural antennas of an antenna array respective plural signals
3 indicative of an arriving wavefront;

4 concurrently using the plural signals provided by the plural antennas for
5 determining both a time of arrival and channel coefficient.

1 22. The method of claim 21, further comprising concurrently using the plural
2 signals provided by the plural antennas for determining plural times of arrival and
3 plural channel coefficients for respective plural arriving wavefronts, each of the plural

4 arriving waveform being represented by one of the plural times of arrival and a
5 corresponding one of the plural channel coefficients.

1 23. The method of claim 21, further comprising essentially concurrently
2 determining the time of arrival and the channel coefficient.

1 24. The method of claim 23, wherein the time channel coefficient is a composite
2 channel coefficient which takes into consideration channel impulse responses for
3 channels associated with each of the plural antennas in the antenna array.

1 25. The method of claim 21, further comprising applying the channel coefficient
2 and the time of arrival to a detector to obtain a symbol estimate.

1 26. The method of claim 21, wherein the step of concurrently using the plural
2 signals provided by the plural antennas for determining both a time of arrival and
3 channel coefficient is performed by a joint searcher and channel estimator situated in a
4 mobile terminal.

1 27. The method of claim 21, wherein the step of concurrently using the plural
2 signals provided by the plural antennas for determining both a time of arrival and
3 channel coefficient is performed by a joint searcher and channel estimator situated at a
4 network node.

1 28. The method of claim 21, further comprising associating each of the plural
2 antennas in the antenna array with an antenna index, and wherein the step of
3 concurrently using the plural signals provided by the plural antennas for determining
4 both a time of arrival and channel coefficient is performed by a joint searcher and
5 channel estimator; and further comprising the steps of the joint searcher and channel
6 estimator:

7 storing a complex value indicative of the signal received in a sampling window
8 in an antenna signal matrix as a function of a sampling window time index and the
9 antenna index;

10 performing a Fast Fourier Transformation (FFT) calculation to generate a
11 correlator output;

12 using the correlator output to generate the time of arrival and the channel
 13 coefficient.

1 29. The method of claim 28, wherein in performing the FFT calculation the joint
 2 searcher and channel estimator considers a dimensional receptivity vector formed from
 3 the antenna signal matrix with respect to a sampling window time index for the plural
 4 antennas of the antenna array, the dimensional receptivity vector having a frequency
 5 related to a difference between phase components of complex values of the dimensional
 6 receptivity vector, there being plural possible frequencies for the dimensional
 7 receptivity, the plural possible frequencies being represented by a frequency index; and
 8 wherein the method further includes:

9 for each combination of plural possible frequencies and plural time indexes,
 10 evaluating the following expression:

11 $Y(n,t) = \text{FFT}(n, X(:,t))$

12 wherein t is the sampling window time index;

13 $X(:,t)$ is the complex antenna matrix, with $:$ representing all antenna indexes for
 14 one sampling window time index;

15 n is the frequency index.

1 30. The method of 29, wherein for each combination of plural possible
 2 frequencies and plural time indexes, the method comprises evaluating the following
 3 expression:

4 $Y(n,t) = \sum C_j * \text{FFT}(n, X(:,t)), j = 1, K$

5 wherein C_j is a coding sequence symbol value j and K is a length of the coding
 6 sequence.

1 31. The method of 28, wherein each of the plural possible frequencies for the
 2 dimensional receptivity vector represents a different possible direction of arrival of the
 3 arriving wavefront.

1 32. The method of 28, wherein the correlator output comprises $Y(n,t)$, and
 2 further comprising determining a maximum absolute value $|Y(n,t)|_{\max}$.

1 33. The method of 32, further comprising:

2 selecting a sampling window time index t_{\max} at which $|Y(n,t)|_{\max}$ occurs as the
3 time of arrival of the arriving wavefront; and

4 selecting a frequency index n_{\max} at which $|Y(n,t)|_{\max}$ occurs as the direction of
5 arrival of the arriving wavefront.

1 34. The method of 32, further comprising determining an amplitude for the
2 arriving wavefront by dividing $|Y(n,t)|_{\max}$ by a number of antennas comprising the
3 antenna array.

1 35. The method of claim 21, wherein each of the plural antennas in the array is
2 represented by an antenna index, and wherein the method further comprises:

3 storing, in an antenna signal matrix, a complex value indicative of the signal
4 received in a sampling window as a function of a sampling window time index and the
5 antenna index;

6 forming a parametric estimate using complex values in the antenna matrix and
7 generating a parametric output estimation vector;

8 using the parametric output estimation vector to generate the time of arrival and
9 the channel coefficient.

1 36. The method of claim 35, wherein each frequency parameter in the parameter
2 estimation vector corresponds to a possible direction of arrival.

1 37. The method of claim 35, further comprising using absolute values of
2 elements of the parametric output estimation vector to determine the time of arrival and
3 direction of arrival of the arriving wavefront.

1 38. The method of claim 37, wherein the parametric output estimation vector
2 has a sampling window time index and wherein for an element of the parametric output
3 estimation vector having a sufficiently high absolute value, the method further
4 comprises using a sampling window time index for an element of the parametric output
5 estimation vector having a sufficiently high absolute value to determine the time of
6 arrival of the arriving wavefront.